

**The Effect of Oil Prices on the Domestic Supply of Corn:
An Econometric Analysis**

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Abstract

In this paper, we attempt to establish a relationship between oil prices and the supply of corn. The main reason we are looking at corn and its relationship with oil prices is because corn is the main feedstock used for producing ethanol fuel in the United States. In our paper, we first examine a simple linear regression model to show that there are omitted variables in the model other than just the price of oil; there are other substitutes for making ethanol as well as other uses for the grains. We then continue with the multiple linear regression analysis by looking at the influence of crop yields for soybeans and sugar and the prices of chicken and pork. With this model, we are able to achieve a relatively high R-squared of 0.8317 which is approximately .2 higher than our R-squared for the simple regression model.

1. Introduction

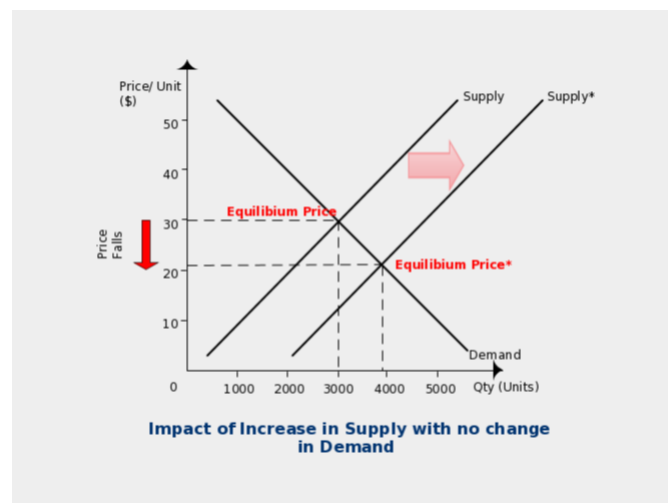
In this paper, we examine the effect of oil prices on the United States' domestic supply of corn. Corn production plays a huge role in the United States' economy and the United States ranks number one in corn production around the world. In the year 2013-2014, the United States produced 13 billion bushels of corn, the majority of which was used in ethanol production. The main use of ethanol is as a motor fuel/fuel additive. It is also important to note that 98% of ethanol is made from corn. Just one bushel of corn can produce 2.8 gallons of ethanol. Ethanol gets blended with gasoline to produce E10 and E85 fuels for automobiles

Since the 1970's, there has been a resurgence in the interest in ethanol and that interest peaked in the 21st century. The United States government started mandating an increase in the use of ethanol in gasoline, and gasoline blends containing up to 10% ethanol began to enter the market. Since then, the U.S domestic market for ethanol consumption has grown mainly due to new federal legislation. The Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 raised the standard to 36×10^9 gallons of renewable fuel used. In 2011, the Environmental Protection Agency allowed up to 15% ethanol blended gas to be sold commercially. With this increase in pro-ethanol federal legislation, the United States has become the largest producer of ethanol in the world. The United States, along with Brazil, produces 87% of the global production of ethanol. The ethanol market share in the United States' gasoline supply has also gone up from 3% in 2006 to 10% in 2011. The United States' domestic capacity to produce ethanol increased fifteen times since 1990 (The United States produced 13.5 billion gallons of ethanol in 2010).

In 2014, crude oil prices (WTI) reached their lowest levels in over 5 years, while ethanol prices continued to increase. This imbalance in price ratios increases the cost of adding ethanol

to gasoline blends, because historically crude oil prices have been going up. This unfamiliar ratio of prices causes uncertainty in the future of ethanol blend and thus uncertainty in the supply of overall corn to the market.

To better illustrate this we can turn to basic microeconomic concepts. The determinants of supply include: production costs, technology, numbers of sellers, and expectation of future prices. The supply of corn is dependent on the expectation of future prices. As the demand for ethanol increases or decreases as oil prices change and the gasoline blends change accordingly, the supply of corn will change as suppliers expect the future price to change.



Graph 1

As graph one shows, if the price of oil increases then there will be additional ethanol demand as the ratio of prices of oil to ethanol in gasoline blends make adding additional ethanol cheaper. This signals an increase in the expectation of future prices which will shift the supply curve to the right as seen in graph 1.

In this paper, we hypothesize that the price of oil is positively correlated with the domestic supply of corn; more corn is supplied to create ethanol as it becomes cheaper to add more ethanol to the blend compared to more gasoline. If our hypothesis is correct, we will have a

better idea on how commodity prices and supply interact and in which direction with each other in these markets. Furthermore, this information can help create new policies and legislation pertaining to ethanol production. We will test against our alternate hypothesis, which states that the price of oil across the United States correlates positively with United States corn production. Our null hypothesis predicts that there is no correlation between the price of oil and the domestic supply of corn.

2. Literature Review

A number of articles and literature exist pertaining to corn demand and supply, ethanol demand and supply, and the relation between the two since the explosion of ethanol production in the 1970's and the 21st century. The following papers provide information on these relationships.

2.1 The Economic Impact of the Demand for Corn

This paper is very similar to ours, but it instead looks at the demand for ethanol and its effect on corn production. It does not use the price of oil. The paper uses two models to find the estimates. One model used was a multiple regression model linking the average price of corn (dependent variable) to production of corn, exports of corn, amount of corn used for ethanol, and a support price of corn. This gave a determined corn price \$0.45/bushel higher than the price would have been in the case if ethanol demand were zero. This model gave an R-squared of .883 which is similar to our multiple regression model (Evans, 1997).

In order to assess the overall effect of ethanol demand on corn price, Evans (1997) estimated a second question in which corn harvested (by acreage) is a function of the price of corn in the previous 2 years. This showed that a \$1.00/bushel increase in the price of corn would

increase the amount harvested by 8.3 million acres. This equation gave an R-squared of .61 so it was much weaker in terms of correlation.

Overall, this paper was more detailed in analyzing the impact of the demand for corn. It used its results to recommend beneficial legislation and attempted to verify the cost-effectiveness of the federal ethanol program. Its analysis concluded that the ethanol industry increases net farm income by more than \$4.5 billion; boosts total employment by 192,000 jobs, and results in a net federal budget savings of over \$3.5 billion (Evans, 1997).

Our paper adds to this as we look at the supply of corn in relation to oil prices, the main ingredient in gasoline, compared to ethanol prices which can be considered a secondary ingredient required by legislation.

2.2 Impact of Renewable Fuels Standard Ethanol Mandates on the Corn Market

This paper looks at the impact on mandated ethanol use which was established by the Renewable Fuels Standard in 2002. It investigates the potential impact of ethanol mandates on equilibrium corn prices and quantities, focusing on how the mandates influence market participant expectations. The first part of the paper cites several other papers that deal with the role of expectation in agricultural economics and emphasizes the importance of rational expectations to policy analysis when policy is known to be affecting the future behavior of prices (Anderson and Coble, 2010). As Shinkwiler and Maddala (1985) state “If producers are rational economic agents, their expectations of harvest prices should be conditioned both by free market forces and the type and degree of governmental intervention in the market”. They use these concepts of expectation to analyze the effect of these policies on the corn market.

Aggregate demand for corn under individual components and under mandated use levels were modeled and an empirical study was done. Using these models they were able to get the

impact if there was or was not a mandate change. Their results were broadly consistent with the behavior of the corn market in 2008. Their assertion is that a non-binding mandate has no effect on current market prices, however, after sensitivity analysis the effect of a binding constraint becomes more apparent as the mandate levels move closer to actual market levels (Anderson and Coble, 2010).

This paper is different from ours as it attempts to measure the effect of the required levels of ethanol in gasoline and its effect on the corn market. Instead of using a regression analysis, they used stochastic principles to model the effects of the mandates and how it will affect the corn market.

2.3 Ethanol Reshapes the Corn Market

This paper was written for the United States Department of Agriculture to determine the effects of increased ethanol production, of upwards of 2 billion gallons, to the corn market. The main question asked was “with the tremendous expansion of the ethanol sector, where will ethanol producers get the corn needed to increase their output (Baker and Zahniser, 2006).” They analyzed different answers to this question to determine the optimum way to get the corn needed to increase their ethanol output.

The first possibility discussed is that ethanol producers will get the additional corn they need by competing with other buyers in the corn market and bidding up the price of corn. The corn suppliers, if maintaining the same supply curve, would have to divert corn for export for domestic ethanol production. This will alter the United States composition for exports.

The second possibility is that farmers will actually shift the supply curve of corn by increasing productivity. This possibility discussed is very close to the relationship we are trying to analyze between oil prices and corn supply. Though no analysis is shown, however, they state

that one of the key factors boosting ethanol demand was the high oil prices at the time of writing (Baker and Zahniser, 2006).

The third possibility discussed is the possibility that new feedstock are used to make ethanol. These include other agricultural commodities such as soybeans, sugar, and sorghum. If the production of ethanol switches agricultural inputs, the corn market could see shrinkage. This is one reason we decided to include substitutes in our multiple regression model (Baker and Zahniser, 2006).

This article did not attempt to establish a relationship as we do but rather takes data and analyzes possible shocks to the corn market. It provides a very good look at the intricacies and relationships in the market but does not quantify them (Baker and Zahniser, 2006).

3. Data

Our analysis requires the use of both a simple and multiple regression model with multiple variables. In the simple regression analysis, the dependent variable is the domestic supply of corn, while the main independent variable is the price of oil per barrel. The multiple regression model includes additional explanatory variables. These variables include the oil, sugar, soybeans, chicken, and pork. Sugar and soybeans are listed by yield in millions of bushels in order to keep units the same with the supply of corn. Chicken is recorded as cents per whole chicken; pork is recorded as cents per pound.

3.1 Descriptive statistics

Table 1 shows the summary of all the data used in this paper. Each variable is recorded per year for the United States through 1988 to 2010. We found accurate data for these sources and felt that the time range took into account enough economic cycles to allow for more accuracy in our model.

Variable	Observations	Mean	Standard Deviation	Min	Max
Corn	25	9468.04	2082.38	4929	13091
Oil	25	29.336	22.731	8.03	85.28
Sugar	25	7780.48	619.92	6691	9032
Soybeans	25	2481.971	508.65	1548	3360
Chicken	25	103.866	20.62	80.17	150.67
Pork	25	244.79	37.68	188.76	311.3

Table 1: Summary Statistics- Summary of all data input into STATA for regression analysis

3.2 Gauss Markov Assumptions

Gauss Markov has 5 assumptions we do not violate. As figure 1 shows that even though there are some high correlations between variables, such as pork and corn, they are not perfectly correlated.

	Year	Corn	Oil	Sugar
Year	1.0000			
Corn	0.8346	1.0000		
Oil	0.7198	0.7175	1.0000	
Sugar	0.6053	0.5054	0.2417	1.0000
Soybeans	0.8043	0.7691	0.4044	0.7046
Chicken	-0.1552	-0.1885	0.0144	-0.1111
Pork	0.9626	0.8284	0.7436	0.5475
	Soybeans	Chicken	Pork	
Soybeans	1.0000			
Chicken	-0.1245	1.0000		
Pork	0.7835	-0.1040	1.0000	

Figure 1: Statistical Correlation between variables

4. Results

The following results were achieved using STATA to perform both a simple linear regression and a multiple linear regression analysis to obtain the estimated equations.

4.1 Simple Linear Regression

Figure 2: Simple linear regression model- STATA output table of Corn Supply vs Price of Oil

Source	SS	df	MS	Number of obs = 25		
Model	63744638.6	1	63744638.6	F(1, 23) = 36.36		
Residual	40327332.4	23	1753362.28	Prob > F = 0.0000		
Total	104071971	24	4336332.12	R-squared = 0.6125		
				Adj R-squared = 0.5957		
				Root MSE = 1324.1		

Supply	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
Price	71.69494	11.89056	6.03	0.000	47.09743	96.29244
_cons	7364.797	437.9623	16.82	0.000	6458.803	8270.791

$$\text{Supply} = 7364.797 + 71.694\text{Price} \quad \text{Equation 1}$$

(437.96) (11.89)

Figure 2 shows that the price of corn is positively correlated with the supply of corn.

With $t = 6.03$ and $P = .0001$, we also find that results are significant at all levels. Our R-squared value, of $R\text{-Squared} = .6125$, is relatively high and supports our positive correlation. However it is still low to consider it a strong relationship which suggests that we omitted some independent variables. We devise a multiple regression model with other important variables we identified through our research.

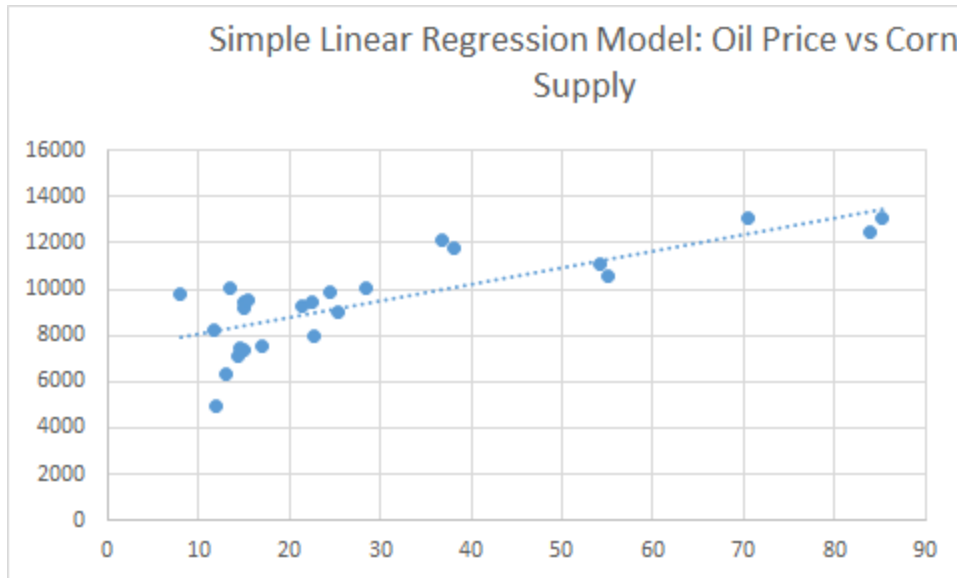


Figure 3: Simple Linear Regression Graph- Oil Prices against Corn Supply

4.2 Multiple Linear Regression

Our multiple regression model regresses the supply of corn to oil prices, sugar yield, soybean yield, chicken prices, and pork prices.

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. regress corn oil sugar soybeans chicken pork
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Source	SS	df	MS	Number of obs =	25
Model	86560523.4	5	17312104.7	F(5, 19) =	18.78
Residual	17511447.6	19	921655.137	Prob > F =	0.0000
Total	104071971	24	4336332.12	R-squared =	0.8317
				Adj R-squared =	0.7875
				Root MSE =	960.03

corn	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
oil	34.86259	15.61952	2.23	0.038	2.170555	67.55463
sugar	.0440322	.4300683	0.10	0.920	-.856111	.9441755
soybeans	1.751233	.7713512	2.27	0.035	.1367768	3.36569
chicken	-10.58324	9.642888	-1.10	0.286	-30.76603	9.599559
pork	9.975167	13.17029	0.76	0.458	-17.59056	37.54089
_cons	2413.546	3116.307	0.77	0.448	-4108.959	8936.051

Figure 4: Multiple Linear Regression Model

$$Supply = 2413.567 + 34.86Price + .044Sugar + 1.75Soybeans - 10.58Chicken + 9.975Pork$$

(3116.307)
(15.61)
(.43)
(.771)
(9.96)
(13.71)

Equation 2

This model shows a more significant R-Squared value than our simple regression model. The R-Squared value goes up by ~.2 to 0.8317 suggesting a much stronger correlation and that the variables included help eliminated any error from the omitted variables in the simple regression model.

Using the T-statistics data we can determine the significance of our variables. We considered variables significant at the 90% level; these variables included oil and soybeans which both are significant at the 95% level. The variables sugar, chicken, and pork do not seem significant and an F-test will be applied to test. These variables may not have as much impact as we thought. Soybeans are the second most used crop in ethanol production which helps explain why it is a more significant variable in the model.

4.3 Robustness Test: F-Test and dummy variables

To test if there is joint significant between sugar, chicken, and pork, we create a restricted model excluding these variables and applying the F-test. The restricted model is shown in figure 5.

Source	SS	df	MS	Number of obs =	25
Model	84725721.6	2	42362860.8	F(2, 22) =	48.17
Residual	19346249.3	22	879374.969	Prob > F =	0.0000
				R-squared =	0.8141
				Adj R-squared =	0.7972
Total	104071971	24	4336332.12	Root MSE =	937.75

Corn	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
Oil	41.61591	10.43218	3.99	0.001	19.98088	63.25093
Soybeans	2.277243	.466211	4.88	0.000	1.310381	3.244106
_cons	2595.143	1024.548	2.53	0.019	470.3609	4719.926

Figure 5: Restricted Linear Regression Model

$$\text{Corn Supply} = 2595.14 + 41.61\text{Oil} + 2.277\text{Soybeans}$$

(1024.54) (10.43) (.466)

Equation 3

$$F = (R^2_{UR} - R^2_R) / q(1 - R^2_{UR}) / (n - k - 1) \quad \text{Equation 4}$$

q = 3: # of restrictions
k = 5: # of independent variables
n = 25: # of observations

The restricted model shows high significance of both Oil and Soybeans, where both variables are significant to 99%. We use equation 4 to calculate an F-test value of .6623. If we use a critical value of 2.69 for a 95% significance value, we fail to reject the null hypothesis. We can then conclude that there is no joint significance of Sugar Yields, Chicken Prices, and Pork prices.

5. Conclusions

There have been many studies that have been conducted on the relationship between oil, ethanol, and corn, although they have been mainly focused on the demand side of things. Our paper, however, looks carefully at the relationship between oil prices and United States domestic supply of corn. Our paper attempts to establish a positive correlation between the two variables in the hopes of providing significant data that can lead to new federal legislation and policies pertaining to ethanol production and for us to get a better idea on how commodity prices and supply interact in these markets.

In our paper, we first look at a simple regression model to show that there are omitted variables in the model other than the price for oil, such as other substitutes used to make ethanol and other uses for the grains. With the simple regression model, we found that the price of oil is positively correlated with the supply of corn. We got a t-value of 6.03 and a p-value of .0001, meaning that our results are significant at all levels. We got an R-squared value of .6124, which strongly supports our positive correlation. The R-squared value, however, is still low and shows that we did omit some independent variables. Because of this we continue on to using a multiple linear regression model and now look at the effect of crop yields for soybeans and sugar and the prices of beef, chicken, and pork on the domestic supply of corn.

Our research establishes a positive correlation between oil prices and the United States' domestic supply of corn. This is an important relationship to establish, because it determines the future of federal and state legislation pertaining to ethanol production. Future studies can be done to further establish this relationship, such as looking the effect of oil prices globally on the supply of corn. By adding more countries, we can further expand our data and research.

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